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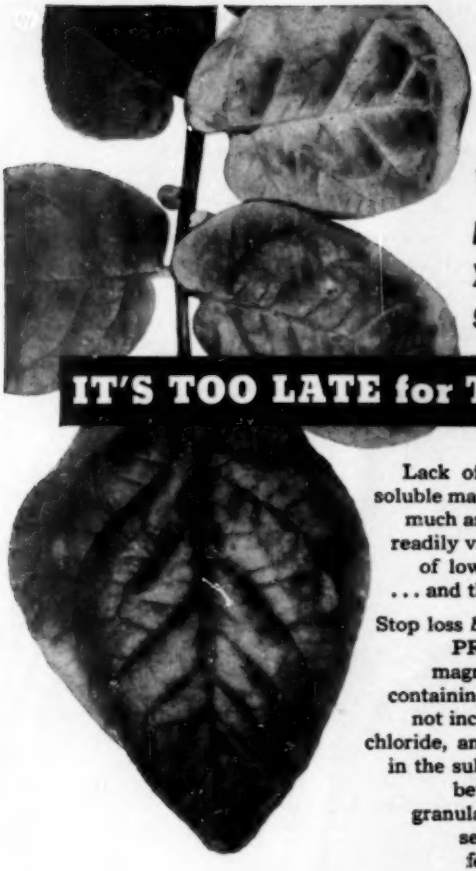

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THE RELATION OF LATE BLIGHT DEVELOPMENT ON POTATO FOLIAGE TO TEMPERATURE AND HUMIDITY[1]

H. DAVID THURSTON, KENNETH W. KNUTSON, AND CARL J. EIDE[2]

Of the various systems (8) devised for relating weather conditions to the development of potato light blight, those based on cumulative rainfall and temperature records have not been found applicable in the north central states (18, 20). On the other hand, that of Wallin and his associates (16, 17, 18, 19, 20, 21) is apparently better adapted to this region and has recently been found applicable in England (9). This system depends primarily upon continuous records of temperature and humidity from hygrothermographs placed 15 inches above the soil in potato fields. The relationship of temperature and humidity to sporulation and infection by *Phytophthora infestans* has been determined with a fair degree of precision in a number of studies (2, 21) but because of the complexity of the ecological factors involved (14, 15) and the imperfections of the hygrothermographs as recorders of microclimatic conditions, the predictions made from such records are necessarily somewhat empirical. Actual tests in the field over a period of time will increase the reliability of the method while basic information is being sought.

Minnesota has cooperated in testing Wallin's system in several parts of the state since 1951 (19). During 1951-1954 inclusive, supplementary studies were made in small plots in which plants were inoculated with *Phytophthora infestans*. Similar studies have been reported by Hirst (3), Wallin and Waggoner (21), and others. Wallin also maintains a "blight garden" to check the accuracy of predictions in Iowa.[3]

MATERIALS AND METHODS

The plots studied during the period 1951-1954 were located at the Institute of Agriculture, St. Paul, Minnesota, and were 120-125 feet long by 15 or 16 rows wide. They were planted with the Irish Cobbler variety, except that in 1951 six plants each of 11 other varieties were planted at intervals among the Cobblers. These differed somewhat in field resistance (non-hypersensitive) but did not seem to interfere with the spread of the fungus in the Cobblers. In 1952 rows 1 and 16 were planted with the Kennebec variety. The Cobblers were planted 16 to 18 inches apart in the row and the rows were 38 inches apart.

Duplicate plots were located on peat and Hempstead silt loam soils about 0.4 miles apart. The silt loam plots were on fairly level ground, relatively unprotected from the wind, and the peat was in a hollow between low hills.

[1]Accepted for publication September 30, 1957.
[1]Paper No. 952, Scientific Journal Series, Minnesota Agricultural Experiment Station, St. Paul, Minn.
[2]Instructor, Research Assistant, and Professor, respectively, Department of Plant Pathology and Botany, University of Minnesota, St. Paul, Minn.
[3]Wallin, Jack R. Crop disease forecasting project. North Central States Annual Report, 1956. Unpub.

Each year, on the first dates shown in the figures 1 to 4, single plants near the center of each plot were inoculated by spraying with sporangia of *P. infestans* from cultures grown on autoclaved yellow peas (10). A clear, still night was chosen for inoculation, and infection invariably followed. The figures also show which races of the fungus were used for inoculation. Hygrothermographs in louvered shelters were placed near the inoculated plants, with the bases of the instruments about 15 inches from the soil.

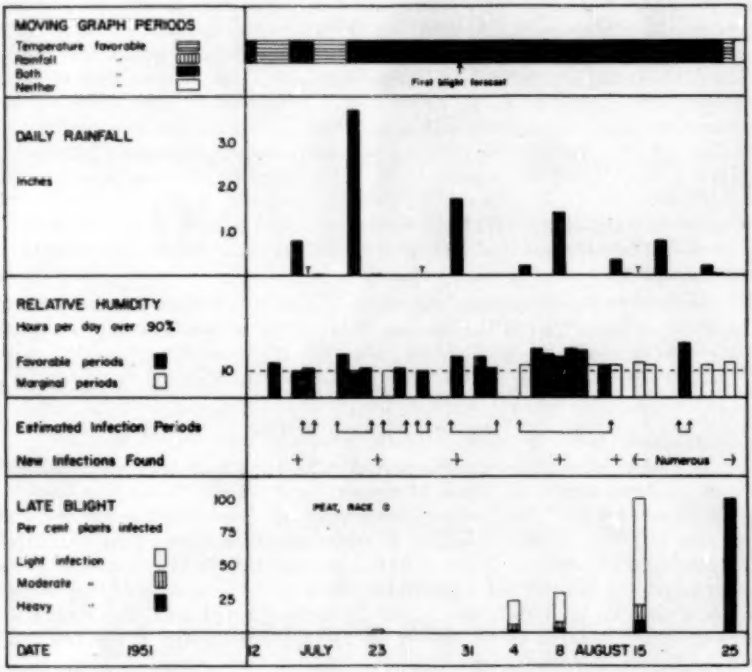

FIGURE 1.—Weather conditions and blight development, St. Paul. 1951.

Notes were taken daily or as often as sporulation and spread of the fungus were apparent. Each row was divided into units 5 feet long and the records of prevalence and severity based on these units. Severity was estimated by the following arbitrary scale:

Light infection—only a few lesions per plant; no appreciable defoliation.

Medium infection—numerous lesions per plant, but less than approximately 25 per cent defoliation.

Heavy infection—more than 25 per cent defoliation.

Early in the season each spread (infection cycle) of the fungus was distinct and relatively easy to follow. Infections were first apparent as minute necrotic flecks which grew larger and finally developed into typical

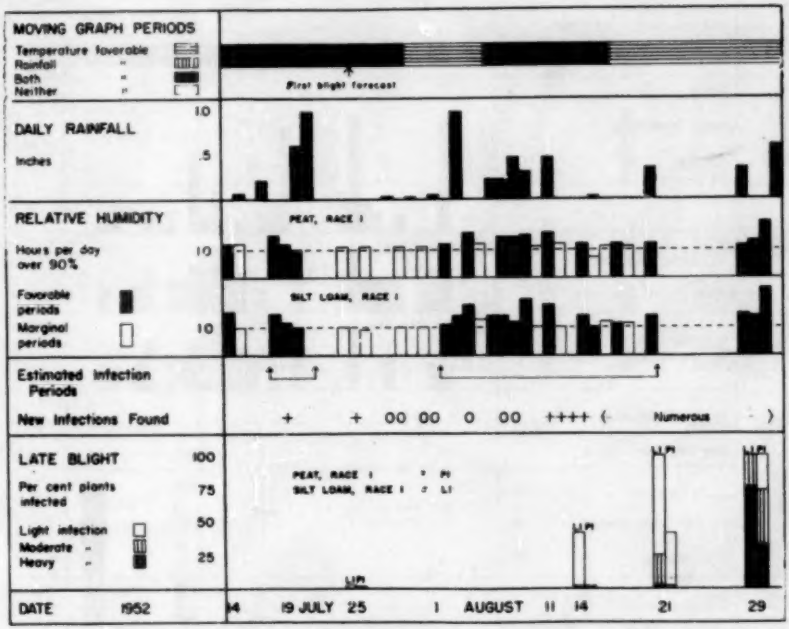

FIGURE 2.—Weather conditions and blight development, St. Paul. 1952

blight lesions. Not until later in the season, when a majority of the plants were infected, did it become impossible to distinguish the lesions resulting from a single infection cycle.

In the figures, a day refers to the time from noon to noon, the date of the second noon being recorded. This permitted the recording of a blight-favorable period as occurring on a single day, inasmuch as they usually began before midnight and continued until sometime the next morning. Rainfall was determined at 8 a.m. on the date recorded, using a standard rain gauge located a few rods from the silt loam plots.

"Favorable periods" for blight development are those suggested by Wallin[4]:

10 hours temperature 60°—77° F., relative humidity 90 per cent +.
12 hours temperature 54°—59° F., relative humidity 90 per cent +.
14 hours temperature 45°—53° F., relative humidity 90 per cent +.

These conditions were considered favorable only if the maximum temperature during the following 24 hours did not exceed 95° F.

"Marginal" periods in the figures were so designated for two reasons: (1) if the humidity was above 90 per cent for more than 10 hours, but the temperature below the designated range or, (2) if a favorable period oc-

[4]Wallin, Jack R. The late blight forecast for the North Central States, June 13, 1956. Mimeo.

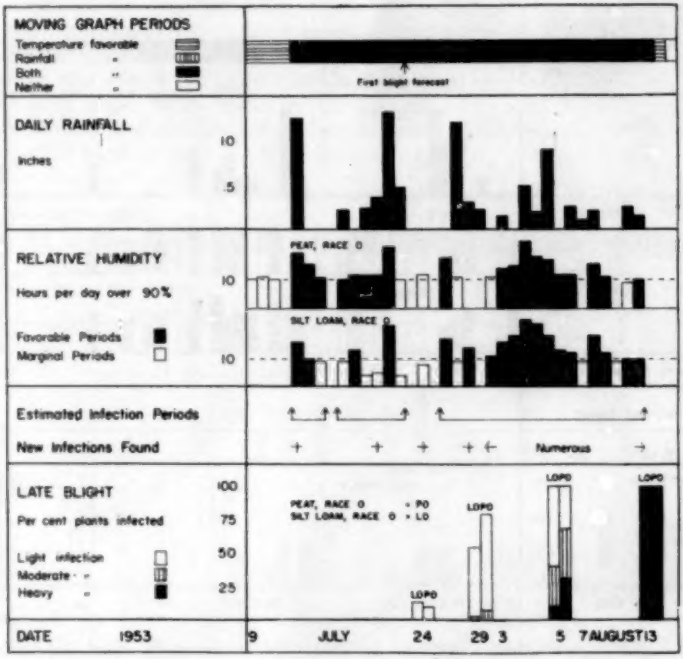

FIGURE 3.—Weather conditions and blight development, St. Paul. 1953

curred in another plot the number of hours of favorable humidity is shown for comparison.

RESULTS

The results of the studies are presented in figures 1 to 4, which are patterned after those of Hirst (3). A "moving graph" record of temperature and rainfall as devised by Hyre (5) is included for comparison. It is based on a 10-day average rainfall of 1.16 inches. A preliminary report of this work has been published (13).

In 1951 a heavy rain submerged the plot on the silt loam, which was in a slight depression with no drainage. The peat plot, although lower, was better drained and sustained no damage. Figure 1 shows that 44 days after inoculation all the potatoes were more than 25 per cent defoliated as a result of almost continuously favorable weather, with breaks of not more than 2 unfavorable days during the first month. There were three distinct infection waves that resulted in the spread of the blight to approximately 25 per cent of the plants. A fourth spread, less distinct, involved the entire plot. The moving graph method of calculation also showed almost continuously favorable conditions.

In 1952 a favorable period (July 18-20) resulted in a single infection cycle with new lesions apparent on July 25 (Figure 2). Cool and relatively

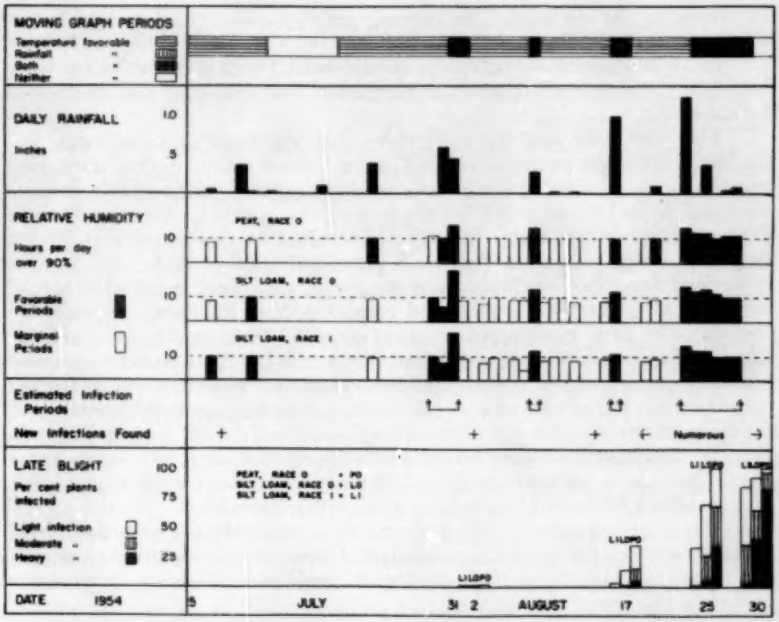

FIGURE 4.—Weather conditions and blight development, St. Paul. 1954

dry weather for 12 days halted further development until August 2, when a series of favorable days resulted in several new infections, first apparent on August 11. On August 21, three weeks after the renewal of favorable conditions, all of the plants on the silt loam and 40 per cent of those on the peat were infected.

The blight spread faster on the silt loam than on the peat. This was apparent at the time of the first spread on July 25 and remained true thereafter. No striking differences in the charts from the two plots occurred before July 25, but thereafter conditions were favorable on three different days in the silt loam plot when they were not so on the peat.

Again in 1952 the moving graph would have accurately forecast the development of the disease through August 16. Thereafter, although the weather appeared too dry for blight as judged by this system, blight continued to spread and increase in severity. However, the increase between August 21 and 29 was probably the result of infections that occurred up to August 21.

The season of 1953 was wet also, with rain on 18 days of the 35 between the time the plants were inoculated on July 9 and August 13 when all plants were more than 25 per cent defoliated (Figure 3). Days favorable for blight were more frequent on the peat than on the silt loam during the first 12 days following inoculation, but even so a slightly greater speed was found on the silt loam after 2 infection cycles (July 24). Thereafter blight appeared to spread more rapidly on the peat although conditions were more

favorable on the silt loam. The moving graph showed continuously favorable conditions during most of the period.

In 1954 (Figure 4) two plots on silt loam, about 400 feet apart, were inoculated wtih races 1 and 0, respectively. The peat plot was inoculated with race 0.

The year 1954 was distinctly drier than the three previous ones, and the initial infection on the inoculated plants did not spread during the period from July 8 to 29. During these three weeks there was one favorable and one marginal period as recorded by the hygrothermographs. After that, three days of favorable periods, July 29-31, resulted in new infections, and a single favorable period on August 8 permitted another cycle of infection. A week of favorable conditions near the end of the month resulted in spread to nearly all plants in the plot, and considerable defoliation, especially on the peat. The more rapid spread on peat occurred between August 2 and 17, when temperature and humidity were very much the same in both plots unless the greater number of marginal periods on peat were important. During many of these periods there were 10 hours of humidity over 90 per cent but the temperature was below the prescribed lower limit of 60 degrees F. However, no new infections were found which might have occurred during those days. Conditions were practically identical on the two silt loam plots, but race 0 seemed to spread appreciably faster than race 1.

The moving graph in 1954 showed only occasional days when both temperature and rainfall would be considered favorable for blight development, and in no case were there 10 days of such conditions which are supposed to precede a blight warning (5).

Discussion

Experiments of this type, too large to replicate and with many obvious sources of error, cannot be used to derive sweeping conclusions about the ecology of plant pathogens. However, they are about the only means of studying the relations of environment to disease under more or less natural conditions. Controlled studies of such things as sporulation, spore liberation, dissemination, survival, germination, and penetration are needed to explain and support field studies, and together form a basis for valid generalizations.

Relation of Hygrothermograph Records to Blight Development

The relation of "favorable periods" to the spread of blight is clearly shown in these studies. The seasons of 1951 and 1953 were too wet to afford contrasting favorable and unfavorable periods, but the response was definite in 1952 after the favorable periods were followed by a cool, dry period from July 20 to 31, and to the short favorable periods of July 29-31, August 8, and August 16, 1954.

Most of the periods favorable to blight, based on the hygrothermograph charts, were also periods of rainfall. This relationship differed with the season, and undoubtedly with the location. For example, Wallin, Wade, and Darling (18) reported that of 45 favorable periods observed at Antigo, Wisconsin in 1951, 23 were on days with no rain. In 1952, 54 of 76 periods were on days with no rain.

A summary of similar relationships in the present study is given in table 1, which shows that in four years 42 periods favorable to spread of blight occurred on rainy days as compared with 32 on days without rain.

TABLE 1—*Relation of rainfall to blight-favorable periods as indicated by hygrothermographs. St. Paul, Minn., 1951-54 inclusive.*

	1951	1952	1953	1954	Total
Favorable Periods on Days with Rain	6	10	14	12	42
Favorable Periods on Days without Rain	12	9	8	3	32
Days with Rain, but without Favorable Periods	8	5	3	5	21

There were 21 rainy days which the hygrothermograph records indicate were not favorable for blight. Relative humidity may fall considerably during showers resulting in periods of less than 10 hours of high humidity.

Relating the spread of blight to rainfall and relative humidity individually was not possible in the studies of 1951 and 1953 because of frequent coincidence of rain and high humidity. In 1952 the moving graph system would have forecast a spread of blight exactly on July 25. Further forecasts during the next six days would have depended upon official weather predictions. A resumption of favorable conditions was indicated by the hygrothermographs on August 2 and by the moving graph on August 6. New infections were found on August 11, which may not have occurred until August 6. Spread of blight continued after that date, although moisture conditions were unfavorable after August 17 according to the moving graph and after August 21 by the hygrothermograph record. A considerable increase in blight severity between August 21 and 29 indicates that there must have been some new infections after August 17.

In 1954, after a relatively long period unfavorable for blight, favorable periods were indicated by the hygrothermographs on July 29-August 1, and by the moving graph July 31-August 1. New lesions on August 2 indicated that infections must have taken place before July 31. Infection periods were indicated by both systems on August 8 and 16 and were followed by new infections several days later.

Although these facts do not separate clearly the effects of rainy and rain-free favorable periods, they do suggest that many of the favorable periods recorded by the hygrothermograph were accompenied by rain. It does not appear necessary to wait for 10 days of favorable weather before predicting blight spread as prescribed by Hyre (5), although this may be true at the beginning of the season while the fungus is becoming established in the foliage. Hyre (6) found that hygrothermograph records are probably of little value in parts of eastern United States, where the moving graph system has been found reliable.

Reliability of Instruments

The hygrothermographs used in these studies were calibrated at least once a week with a bulb-aspirated psychrometer, and only during the first few days of the seasons were more than minor adjustments necessary. In 1954 when two instruments were in similar plots only 400 feet apart, the charts were practically duplicates of one another. Under these conditions the

records from instruments of this type seem very reliable, if the humidity element is calibrated in a humid atmosphere over the range where greatest accuracy is desired. Although it is not usually possible to calibrate the instruments in farmers' fields as frequently as desirable, most of those used during a period of 5 years were reasonably accurate when checked with the psychrometer. Temperature records are highly accurate.

Relation of Humidity and Temperature Records to Rate of Blight Development

Although hygrothermograph records made at crop level are useful in predicting the occurrence of infection cycles by *Phytophthora infestans*, they were not found in these studies to be sufficiently precise to account for differences in amounts of infection. It was expected that blight would spread faster on the peat plots, but this was not true in 1952. Conditions that year, as indicated by the hygrothermographs were slightly more favorable on the silt loam, but hardly enough so to be convincing. The peat plot was not fertilized that year, and the plants were smaller than those on the slit loam. This would be expected to result in longer periods of high humidity and to provide more favorable conditions for the sporulation and infection by the fungus. If such were the case, the differences in conditions were not very striking on the hygrothermograph charts. In 1953 differences in the amount of infection on peat and silt loam were slight and not associated with the hygrothermograph records. Slightly faster spread in the peat plot in 1954 cannot be accounted for by the records of temperature and humidity.

Wallin and Waggoner (21) found that the temperature and humidity on peat and mineral soils differed to a small but significant degree. They concluded, however, that the differences were inconsequential, and that the greater blight development on the peat was because the plants were more rank and vigorous.

Theoretically a small difference in the number of infections on the plant originally inoculated would be increased with each infection cycle if the same proportion of spores infected each time conditions were favorable for infection. A favorable period in one plot but not the other would have the same result. No increase in the differences in blight severity or prevalence in comparable plots was observed as the season progressed in these studies. If anything, such differences tended to become less later in the season.

Waggoner (15) has pointed out some of the complexities involved in the epidemiology of pathogens such as *Phytophthora infestans* which serves to emphasize the difficulty of correlating disease spread with small differences in only two of the factors involved. It can only be concluded here that while there are indications of the effect of such differences, they were too small to be impressive.

Relative Rate of Spread of Different Races

Thurston, *et al* (11, 12) have shown that in mixtures of races of *P. infestans* certain isolates of race 0 will replace those of race 1 in the course of several generations on potatoes in the greenhouse. It is also apparent that race O is the predominant one naturally present wherever susceptible varieties are present. To see if these facts were associated with greater aggressiveness, similar plots inoculated with races 0 and 1 were planted in 1954. As shown in figure 4, race 0 apparently seemed to spread faster, having in-

fected twice as many plants as race 1 by August 25. Five days later the number of plants infected by the two races was nearly the same, but the severity was much greater in the race 0 plot. It seems probable that this represents a real difference in aggressiveness, as temperature and humidity were nearly identical according to the hygrothermograph records.

Application to Field Conditions

While these studies confirm previous results in showing that the late blight fungus will sporulate and reinfect within the limits of a short period of favorable temperature and humidity, it should be remembered that the fungus was established in the foliage at the beginning of the experiments. Similar spread may logically be expected to occur in commercial fields, within the limitations of varietal resistance and the effects of fungicides. However, the effects of weather on the early development of the fungus from infected tubers is poorly understood, although work on this has been published (2, 6). That a certain amount of time is necessary for the establishment of the fungus in the foliage is recognized in the "critical dates" set by Cook (1) and the 10 days of favorable weather prescribed by Hyre (4) in his system, and by Large's observation (7) that "flushes" of favorable weather in June are usually not followed by outbreaks of blight.

In actual use, the hygrothermograph records are subject to the same limitations especially in areas where primary inoculum is absent or scarce in many years. For example, in 1955 in Minnesota, during 11 weeks there were 26 favorable periods at Donaldson, 37 at Glyndon, and 36 at Williams. Blight was found at Williams after 7 weeks and 20 favorable periods, and later became epidemic. In the Red River Valley, where Donaldson and Glyndon are located, blight was widespread but very light. If it had been present early in the season, it should have become epidemic, judging from the hygrothermograph records from the area and the results of the present plot studies. The use of fungicides would be expected to check the disease somewhat, but laxity in this practice is sufficiently common in the area so that some spread should have occurred. Obviously, studies of the early development of the disease under these conditions are needed. For practical purposes, in areas where primary inoculum is not always present, hygrothermograph charts should be used in conjunction with a thorough survey of the fields to determine when the disease first becomes apparent in the foliage.

Summary

During four seasons, late blight on the foliage of potato plants spread to nearby plants during periods described by Wallin and his coworkers as "favorable," *i.e.* 10 or more hours of relative humidity above 90 per cent and temperatures between 60° and 77° F.

Over 56 per cent of the favorable periods in the 4 years occurred on days with rain. In most instances Hyre's "moving graph" system of relating weather to blight would have indicated periods of spread accurately.

The rate of spread of blight differed in plots on peat and silt loam soil, but the differences were not definitely associated with differences in temperature and humidity recorded by the hygrothermographs.

It appears that in regions where primary inoculum occurs sporadically, the prediction of blight development by the use of hygrothermographs

should be supplemented by surveys to determine if centers of infection exist in the fields.

In a single comparison, race 0 of *Phytophthora infestans* spread more rapidly than race 1 in a similar plot.

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NEWS AND REVIEWS

POTATO PROCESSING IN DENMARK[1]

E. KISSMEYER-NIELSEN[2]

A large portion of the Danish soil is sandy and on this soil potatoes are among the crops which are most profitable and most reliable. They are part of the crop rotation on dairy farms in the sandy sections of Denmark. In the Potato Journal, Volume 34, No. 1, in the article "Potato Industry in Denmark" a rather detailed description of this industry is given. Among the endeavors to enlarge this industry for many years have been attempts to use large quantities of potatoes for processing. Two of the most successful endeavors are processing potatoes into starch and alcohol. The former has, especially since 1933, shown a very steady development. The latter is gradually declining in significance because other raw materials have been substituted for potatoes such as sugar beets and by-products from a newly formed Danish oil refining industry. The potato starch industry has since 1933, been backed and regulated by the government which only allows seven factories to process potatoes for starch. They are not given any subsidies, but imports of other starches are strictly regulated and almost prohibited. The government controls the price of the finished potato starch on the Danish market. There are a few other potato processing industries of less significance, such as potato chip plants and potato granule plants. These plants will not be described in this paper.

THE ORGANIZATION OF THE POTATO STARCH FACTORIES

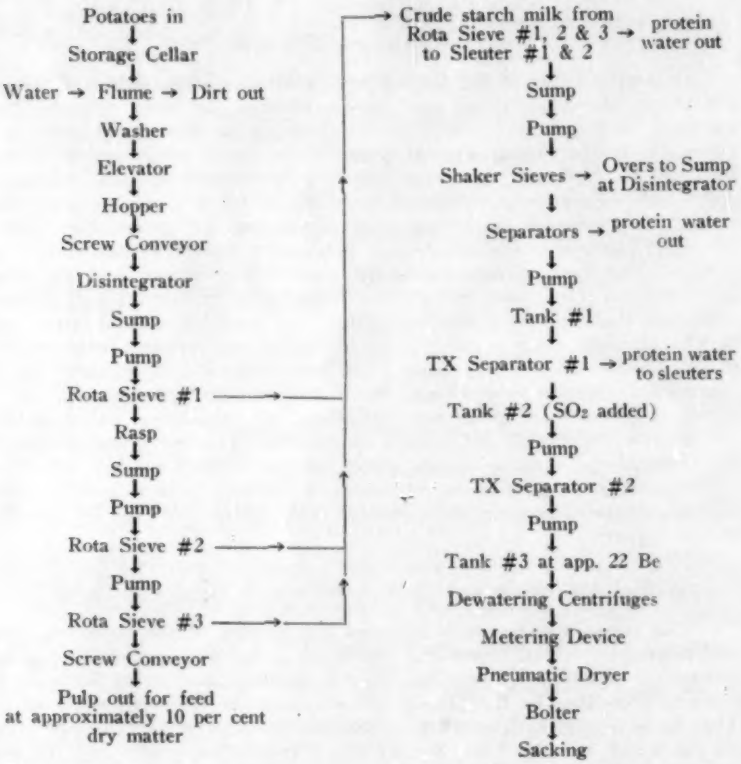
The seven potato starch factories are located in the most important potato growing areas. They are organized as farmers cooperatives. Their processing capacities vary slightly. All profits are divided between the farmers according to the amount of starch units delivered each season. They have a sales organization in common in Copenhagen through which all the starch is sold. Each factory has a production quota and the sales are divided between the factories according to this quota. Consideration is given to any special starch desired on behalf of the customers. The starch does not differ greatly from factory to factory, however. The quality control is conducted by the same laboratory which is in no way connected with any of the individual factories. Each factory has its own board of directors, consisting of local farmers. These are elected at the annual general meetings. The chairmen of these boards meet occasionally in the sales organization and here discuss various questions which the factories have in common.

POTATO STARCH PRODUCTION PROCEDURES

All the potato starch factories are equipped with up-to-date equip ment. A flow sheet of potato starch production is given on page 408. There are naturally, variations in this procedure from factory to factory.

[1]Accepted for publication October 10, 1957.
[2]Assistant Manager, Potato Starch and Granule Factory, Harlose, Denmark.

Flow Sheet of White Potato Starch Process Used in Denmark.



Weighing in, Sampling and Unloading of the Potatoes. The greater part of the potatoes come in on trucks. The trucks are weighed upon arrival and when leaving. Samples are taken from each load and the starch content is measured by determining the specific gravity of the potatoes. The dirt-percentage is judged by appearance, and the potatoes are then unloaded into cellars and flumed into the factory.

Washing of the Potatoes. The potatoes are usually washed in washers equipped with wooden paddles which move the potatoes forward through the washer against a stream of fresh water. From here the potatoes are conveyed to a hopper. Various types of stone traps are used before the washer.

Grating of the Potatoes. From this hopper the potatoes are led to either a saw tooth rasp or a disintegrator for the initial grating. The disintegrator is a hammermill where the hammers are mounted on a vertical axle directly connected to the el-motor. The lower end of this

axle with the hammers is set into a housing of heavy cast iron in which is mounted a finely perforated steel plate. The axle rotates at approximately 3000 RPM. The potatoes are reduced to a rather fine pulp in this disintegrator. Most of the cell walls are broken and the starch granules freed. This pulp is led to a sump and from here to a Rota Sieve or other type of pulp washer. All the pulp that does not pass the sieve is led to a saw tooth rasp. The ground pulp from here is led to a second pulp washer and the overs are then led to a third washer and out the factory for cattle feed at approximately 10 per cent dry matter. The crude starch milk from the three washers is led to Starcosa separators. In these the protein water is separated from the solids and carried out the factory. A slurry of the solids from the sleuters is led into a sump and from here it is pumped to shaker sieves. The overs from these are led back to the sump under the initial grating and thus back into the process.

The Purification of the Crude Starch Milk

The crude starch milk from the wet sieves is purified by leading it through various types of separators and perhaps also centrifuges. Very often the LaVal TX Separators play an important part in this purification. These LaVal Separators are rotating at a very high speed. The rotating body consists of a metal disk arrangement where the particles in the slurry are separated by gravity and led out through various openings making it possible to do a very accurate sorting of the particles in the slurry. There are very often two such separators. The purified slurry from the first separator is led to a tank and from here to the second separator after adding SO_2. The purified starch slurry from the number 2 TX is led to dewatering centrifuges and dehydrators. Sometimes a Starcosa Purificator is used instead of the TX Separators. This purificator is a vertical spinning solid bowl centrifuge. The principle is that the wet starch slurry is led into this purificator and is allowed to spin in this for a few minutes. A fine layer of impurities is formed on the inner side of the starch slurry and scraped off with a knife. The purified starch slurry is then led to the dewatering centrifuges and other equipment for dewatering the starch slurry.

There are other excellent means of purification than mentioned here.

The Dewatering of the Starch Slurry

From a holding tank the purified starch slurry at approximately 22 Be° is led to a dewatering device. Until recently most factories used dewatering centrifuges. These are vertically spinning bowls where the sides are made up of a heavy wire mesh dressed with a fine cloth. A certain amount of purified starch slurry is led into the spinning bowl. After a few minutes so much water is thrown out of the starch slurry that a solid mass of starch at approximately 38-40 per cent moisture remains and is scraped out with a knife and led to the dehydrator. Recently the Danish Machine Company, Anhydro, specializing mainly in pneumatic dehydrators and spray dryers and other types of dryers has constructed a rotating vacuum filter which is claimed to take out so much water from the starch slurry that only approximately 38 per cent remains. This filter has now been installed in several of the starch factories. It affords great advantages

above the dewatering centrifuges because it demands very little attention and because it feeds directly into the pneumatic dryers at a very constant rate. It must, however, be mentioned that there are automatic dewatering centrifuges. Starcosa is said to manufacture a continual horizontal shaft dewatering centrifuge

Drying. All but one of the seven starch factories now use pneumatic dehydrators. The principle in this type of dehydration is that the starch from the dewatering device is metered into a hot air stream in pipes. Here the starch is dried down to approximately 20 per cent water and separated out from the air in a system of cyclones. Most of these dehydrators are manufactured by Anhydro. They involve a great simplification of the drying operation because they demand very little attention. They convey the starch wherever it is needed for bolting and sacking. There is no evident waste of starch through the outlets from the cyclones. The utilization of the water retaining capacity of the hot air is rather high. It is a flash drying which allows very little time for changes in the molecular structure of the starch molecules. There are also various other types of good dehydrators. One factory uses the Buttner-Starcosa drier which is said to be very efficient.

Sifting of the Dried Starch. Here various types of bolts are used but mainly the common flour. This step affords no great problems, and will not be discussed in this paper.

Weighing and Bagging. The starch is weighed on government controlled scales. The Berkel scales seem to be used most extensively. The starch is put into multiple-wall kraft paper bags and stored in .well constructed storages. One of the factories has automatized its sacking and weighing operations. No one has introduced silos in which to store the dried and sifted starch. It is a current thought to introduce silos for at least 2-3 shifts to cut labor cost by only sacking and weighing during one shift and use more automatic weighing and sacking methods. A lot of the starch is exported in a great variety of bags and weights. Therefore, there is great interest shown in introducing large silos for this type of sales, thus sacking directly from the silos, and preventing loss of sacks when desacking.

Derivatives of Starch

Currently a great deal of work is being done to introduce new starch derivates for household and industrial uses. One starch factory is selling a derivative of starch which gives a very nice finish to household linen. Adhesives and glucose are not made by any of the factories.

A Discussion of the Potato Starch Manufacturing Process As Described Above

With the increased interest in derivatives of starch in Denmark the process of manufacturing potato starch must be revaluated. Some of the factories are becoming increasingly interested in manufacturing real high quality starch, *i. e.* they are seeking to purify the starch further and some interest is centered around the size of the potato starch granules. In former years when tabling of the potato starch slurry was used it was possible to separate the larger potato starch granules from the smaller ones. In

France, even today one of the foremost starch chemists in Europe uses this method in an otherwise very modern potato starch factory because he considers it the best method. The initial grating step seems to produce the larger potato starch granules. Starch granules are not damaged in this step to as high a degree as later in the process, and this starch has less cell-wall fibers than the second grating. The newer type pneumatic dehydrators makes it possible, almost instantly, to change from one grade of starch to another. Therefore, there is some interest in dividing the starch into various grades by keeping the starch slurry from the initial grating process apart from the starch slurry from the second grating process. It is also thought best not to lead the fractions containing mixtures of impurities and starch from the separators back into the process, but to keep them apart and clean them separately. This means that the heavier fractions are kept apart from the lighter fractions, giving some grading of large starch granules from the smaller starch granules. The inferior grades, when thoroughly purified can be used in the glucose industry, whereas the superior grades, containing large potato starch granules, are especially suitable in the adhesive industry and for purposes where gelatinized starch slurries of a high viscosity are desired. Then, too, purification of the fresh water for processing is considered further in respect to traces of mineral salts and ions because these may influence the viscosity of the gelatinized starch.

Statistics

Table 1 shows various important statistics from all seven factories in the 1956-1957 season. The variations in the amount of potatoes processed are unusually high because of the surpluses of potatoes which made it necessary to prolong the season and especially so at 'Grimstrup', 'Brande' and 'Karup'.

Summary

The processing of potatoes in significant quantities is becoming limited to the production of potato starch and derivatives. There are other potato processing industries such as potato alcohol, potato granules, potato chips and sticks. The potato granule plant uses a standard production method as used in U. S. A. with certain modifications—though. The author could describe this process in detail and discuss the various steps in this process from storing to packing operation but various circumstances prohibit this description. The volume of this product is, however, not significant. The same applies to chips and sticks. The cold Danish climate and the types of potato varieties grown make processing into these products difficult from a chemical point of view. The sugar-starch ratio is not advantageous. A great deal of work is constantly being done to find new outlets for potatoes through refined products.

TABLE 1.—*Statistics Based on Certified Accounts from the Season 1956-1957.*

	Auning	Brande	Dybvad	Grimstrup	Karup	Toftlun	Videbak
Purchase of "Clean" Potatoes. (metric tons)	14.248	19.164	15.330	23.211	18.294	16.415	14.269
Production of Potato Starch. (Metric tons)	2.955	3.701	2.817	4.084	3.574	3.029	2.727
Average Starch in Purchased Potatoes (Per cent)	16.84	15.88	16.00	15.14	16.55	15.77	15.35
Cwt. Potatoes per Cwt. Starch	4.83	5.18	5.44	5.68	5.12	5.42	5.23
Paid per Pound Starch Received. (Cents)	5.1	5.3	4.9	5.0	5.5	5.0	5.1
Paid per Cwt. Potatoes, $	0.88	0.84	0.80		0.91	0.83	0.80
Production Cost, Cwt. Finished Starch	60	72	73	65	64	75	90
Repair & Maintenance, Cwt. Finished Starch	17	7	10	2	11	21	10
Management Cwt. Finished Starch	17	14	20	12	13	17	24
Interest per Cwt. Finished Starch	19	10	23	12	7	22	13
Cost (Not-depreciated) of Equipment and Buildings	14.000	0	15.900	14.000	0	0	10.000

Total purchase of potatoes, clean basis .....metric tons 120,932
Total production of finished potato starch ..... " " 22,888
Average cwt. clean potatoes used per cwt. finished starch 5.28
Average per cent starch in 120,932 metric tons of potatoes 15.93

Explanations: The finished starch contains approximately 20 per cent moisture. When considering the figures, pounds of potatoes used per hundredweight finished starch, it is necessary to know that the per cent of dirt is not measured, but judged by appearance. It is also necessary to know that the per cent of starch *versus* specific gravity of potatoes may vary somewhat from area to area. The interest noted above is the interest paid on bank loans. None of the seven starch factories is self-financed, because all profits are annually divided between the coop-farmers. Only very insignificant amounts are laid aside.

MINUTES OF EXECUTIVE COMMITTEE MEETING

Plant Industry Station—Beltsville, Maryland
December 1, 1957—5:00 P.M.

Present—Members: R. W. Hougas, E. J. Wheeler, C. B. Frutchey, W. G. Hoyman, O. C. Turnquist, W. J. Hooker, N. M. Parks, J. C. Campbell. Visitors: R. V. Akeley, S. J. Peloquin, R. Webb, G. H. Rieman, D. A. Young, L. C. Young.

Discussion: Regarding length of papers and length of abstracts of papers to be presented at the annual meetings. Motion made by W. G. Hoyman that the presentation of papers be limited to 15 minutes unless the paper is of special nature such as an invitational or symposium type paper. Seconded by E. J. Wheeler. Motion passed. Motion made by W. G. Howman that abstracts of the papers be limited to 250 words. Seconded by O. C. Turnquist. Motion passed.

Discussion regarding the number of honorary members of the Potato Association of America to be elected for 1958. It was agreed that for 1958 there shall be 2 technical representatives and 1 from industry. Discussion regarding location of next meeting. Motion was made by W. G. Howman that the next meeting place he held with AIBS, American Horticultural Society and American Phytopathology Society in Bloomington, Indiana, August 24-28, 1958. Seconded by W. J. Hooker. Motion passed.

Discussion regarding establishment of the office of president-elect. Motion made by W. J. Hooker that the office of president-elect be establishe. Seconded by W. G. Hoyman. Motion passed.

Motion by N. M. Parks that the committee for arrangements for 1959 composed of R. H. Larson, Chm., Ora Smith, L. C. Young and Don MacLachlan should continue (1) to work with the International Botanical Congress in Canada regarding 1959 meeting and (2) to make plans for the program such as symposia and for invitational papers. Seconded by J. C. Campbell. Motion passed.

Discussion regarding bringing the Constitution and By-Laws up to date. The policy committee was directed to make recommendations to the Business Meeting on December 2, 1957.

Motion made by C. W. Frutchey to authorize the treasurer to invest $2000.00 or more in guaranteed deposit to protect future publication of the American Potato Journal. Seconded by O. C. Turnquist. Motion passed.

Respectfully submitted,
W. J. HOOKER, *Secretary*

MINUTES OF ANNUAL BUSINESS MEETING OF THE POTATO ASSOCIATION OF AMERICA

Plant Industry Station—Beltsville, Maryland
December 2, 1957

Meeting called to order by President R. W. Hougas at 10:00 A.M.

Address of welcome—Dr. F. P. Cullinan, Assoc. Director of the Crops Research Division, Agricultural Research Service, U. S. D. A.

President Hougas called for reports of the standing committees as follows:

Program committee: W. J. Hooker—Early submission of papers to

the Journal was urged. A symposium on Quality Maintenance of six invitational papers was presented. Research papers were: 16 in pathology, 6 in breeding and 21 papers on processing and quality control.

Membership Committee: N. M. Parks — It was urged that every member of the Potato Association of America recruit one new member of the society. Report accepted.

Local Arrangement Committee: M. J. O'Brien — Miss O'Brien reported for R. E. Webb that the committee had prepared a map of the Beltsville-Washington area and a list of motels and hotels with their rates for publication in the Journal. Report accepted.

Editorial Board: J. C. Campbell—A resolution was made extending our appreciation to the Secretary of the Treasurer and Editor for her assistance during the year in handling all his correspondence. He requested that a token payment of $25.00 be given her. Report accepted.

Sustaining Membership Committee: J. C. Campbell—Reported that at present there are 14 sustaining members. Report accepted.

Honorary Life Membership Committee: C. W. Frutchey—Reported that three new honorary life members had been elected. They are Reiner Bonde (Maine), F. J. Meyer (Wisconsin), and William Black (Scotland). Report accepted.

Policy Committee: R. V. Akeley—Discussed advantages of having a president-elect and motion was made by R. V. Akeley that the office of president-elect be created and that the person in this office be a member of the executive committee and that the constitution and by-laws be amended accordingly. Seconded by G. H. Rieman. Motion carried.

Potato Certification: Paul Eastman—Report accepted.

Late Blight Investigations: M. E. Gallegly—Report accepted. (This report appears on page 417).

Virus Disease Investigations: R. E. Webb—Report accepted.

Potato Utilization Committee: Kris Bemis—Report accepted.

International Relations Committee: R. H. Larson—Report accepted.

Local arrangements for 1959 in Canada Committee: Report accepted.

Respectfully submitted,
W. J. HOOKER, *Secretary*

MINUTES OF BUSINESS MEETING

Plant Industry Station—Beltsville, Maryland
December 3, 1957

Motion by G. H. Rieman that the minutes of the 1956 annual business meeting be approved as published. Seconded by N. M. Parks. Motion carried.

Financial report of the fiscal year—August 1, 1956 - July 31, 1957: J. C. Campbell reported a balance of $6,573.19 and moved acceptance of the report. Seconded by Paul Eastman. Motion carried.

Auditing committee— O. C. Turnquist reported that the Treasurer's books were in order and moved acceptance of the report. Seconded by E. J. Wheeler. Motion carried.

Executive Committee report—W. J. Hooker.

Motion by L. A. Dionne that the 1958 meeting be held with AIBS, at Bloomington, Indiana, August 24-28, 1958. Seconded by Henry Darling. Motion carried.

Motion by N. M. Parks that the 1959 meeting be held in Fredericton, Canada, just prior to the Botanical Congress. Seconded by L. A. Dionne. Motion carried. The committee previously appointed, R. H. Larson, Chairman, for planning the 1959 meeting was advised by President R. W. Hougas to continue its activities.

Motion by M. E. Gallegly that the 1960 meetings be held at the Baptist Assembly Grounds, Green Lake, Wisconsin. Seconded by D. S. MacLachlan. Motion carried.

Motion by R. V. Akeley that if the 1959 Handbook is published that the theme be potato varieties and breeding. Seconded by H. M. Darling. Motion carried.

Motion by J. E. Livingston that the executive committee be empowered to decide if the 1959 issue of the American Potato Handbook should be published. Seconded by R. H. Larson. Motion carried.

Nominating committee report—J. W. Scannell. Motion by C. W. Frutchey that the nominations for President, N. M. Parks; Vice-President, Paul Eastman; and President-Elect, W. J. Hooker be closed and that a ballot be cast by the Secretary. Seconded by L. A. Schaal. Motion carried.

D. S. MacLachlan was elected by ballot as a new director.

Motion by L. A. Schaal that the Executive Committee be instructed to explore the possibility of inviting the Potato Utilization Conference to meet with the Potato Association of America. Seconded by Paul Eastman. Motion carried.

Resolution proposed by O. C. Turnquist. "Be it resolved that the Potato Association of America extend our sincere appreciation to the local committee at the Plant Industry Station at Beltsville; especially Dr. Webb, Mr. Akeley, Dr. Buck, and Miss Muriel O'Brien for the excellent arrangements they have made toward making our 1957 annual meeting a success." Resolution passed unanimously.

Motion for adjournment passed.

Respectfully submitted,
W. J. HOOKER, *Secretary*

MINUTES OF EXECUTIVE COMMITTEE MEETING

Plant Industry Station—Beltsville, Maryland
December 3, 1957

Present—R. H. Hougas, Chm., N. M. Parks, J. C. Campbell, D. S. MacLachlan, Paul Eastman, O. C. Turnquist, E. J. Wheeler, W. J. Hooker.

Robert V. Akeley was elected secretary of the Association for the two-year term 1958-1959.

Motion by O. C. Turnquist that a committee be named to explore the possibility of closer cooperation with the Potato Utilization Conference. Seconded by J. C. Campbell. Motion carried.

A policy of limiting committee reports in future years to 15 minutes was adopted.

A policy of maintaining continuity of committee membership was adopted. Not more than 2 members of each committee may be dropped

FINANCIAL REPORT
POTATO ASSOCIATION OF AMERICA

For the Fiscal Year

August 1, 1956 to July 31, 1957

RECEIPTS

Cash on hand and in bank, July 31, 1956			$5,277.47
Annual dues			6,432.52
Sale of advertising in Journal			1,932.61
Sale of reprints			2,224.20
Sale of back issues			334.11
General			14.60
Receipts from 1957 Potato Handbook			
Sale of advertising	3,055.49		
Sale of Handbooks	221.15		
		3,276.64	
Sale of advertising for 1958 Handbook			10.00
Total receipts			$19,502.15

DISBURSEMENTS

Printing of Journal			$4,928.66
Printing of reprints			894.28
Mailing and supplies			817.68
Salaries, E. Campbell (Treasurer's work)			695.00
J. Campbell (Editorial work)			629.00
E. Clark (Editorial work)			335.00
Commission on advertising in Journal (Hutchinson)			244.71
Expenses connected with annual meeting			210.35
AIBS dues			100.00
General (Telegrams, telephone, advertising, etc.)			43.19
Expenses of the 1957 Handbook			
Editing (Hutchinson)	625.00		
Commission on ads (Hutchinson)	392.74		
Secretarial work (Hougas)	48.45		
Printing and mailing	2,379.07		
		3,445.26	
Expenses of 1958 Handbook (Hutchinson)			
Commission on ads	2.50		
Editing	583.33		
		585.83	
Total disbursements			$12,928.96
CASH ON HAND AND IN BANK, JULY 31, 1957			$ 6,573.19

LELAH STARKS FUND

Cash on hand in Savings account, July 31, 1956		$ 520.08	
Interest		10.46	
Total			$530.54
Total cash assets			$ 7,103.73

each year and the advice of the previous committee chairman may be obtained in making appointments.

The duty of the president-elect was designated as that of coordinating activities of all committees and seeing that they function. Committees are responsible to the president-elect.

A special committee on cytology and genetics shall be named for 1958.

Special committee on varietal description was designated. O. C. Turnquist, Chairman.

Motion by W. J. Hooker that the Potato Handbook be published in 1958. Seconded by J. C. Campbell. Motion carried.

Respectfully submitted,
W. J. HOOKER, *Secretary*

LATE BLIGHT INVESTIGATIONS

COMMITTEE REPORT—1957

M. E. GALLEGLY, *Chairman*, REINER BONDE, C. J. EIDE, J. L. HOWATT, J. S. NIEDERHAUSER, L. C. PETERSON, W. R. MILLS AND R. E. WEBB.

Work with potato late blight during 1957 has continued along the lines discussed in the committee report of 1956 (American Potato Journal 34: 108-111). As before, the thoughts and activities of the committee have been concerned mostly with the problem of resistance to the disease and physiologic specialization of the pathogen.

Field resistance to late blight.—During the year 1957, North American potato breeders and pathologists continued to give increasing consideration to the development of potato varieties with high levels of field resistance to late blight. Although there has been some shift in emphasis from dominant-gene resistance, most workers desire to combine both types of resistance in a commercially acceptable variety. The shift in emphasis from breeding only for the dominant R-gene resistance to breeding for field resistance in addition to R-gene resistance began about 1952 in Mexico and Minnesota and is still going on. The reason for this shift is increasing evidence that the late blight fungus is unstable with new specialized races developing rapidly and attacking varieties containing the dominant R-genes, whereas field resistance, controlled by the operation of a polygenic system, gives general resistance to the R-gene specific races. Thus, when dominant-gene resistance gives way due to the appearance of a specific race, field resistance will be present in a variety to prevent the disease from becoming serious.

A number of workers have been concerned with developing methods of measuring the degree of field resistance in plants so that screening and selection may be effectively carried out in the greenhouse. Plants with only the polygenic type of resistance are susceptible to all races of the fungus, but under field conditions may be only slightly diseased, whereas under the same conditions, plants without this resistance are killed. In the past, many workers have found that the differences in resistance observed in the field cannot be measured with the usual inoculation tech-

niques. Also, without the proper physiologic races, the presence of dominant genes may give an immune reaction masking the presence of field resistance.

Canadian workers indicate that their temperature-humidity controlled blight chamber may be used successfully to measure the degree of field resistance in a clone. Using race *1,2,3,4* to test a large number of European and American varieties, they found a wide range of differences in resistance to infection. In Minnesota, several clones with field resistance have been selected following natural infection and artificial inoculation with selected races. They report that artificial inoculations may not give satisfactory results unless an isolate with a high degree of aggressiveness (virulence) is used. Their 1957 field tests were disappointing because the race used by them was apparently low in aggressiveness. The rate of lesion development was used by West Virginia workers as a measure of the degree of field resistance in a large rating and actual performance in the field in Mexico.

At present it appears that the most effective method of selecting for field resistance is to expose clones in the field during the summer in Mexico where all known physiologic races occur naturally Since these races will attack plants with the dominant-gene type of resistance, the masking of field resistance by the immunity reaction is eliminated. Workers in Mexico report that they have discontinued greenhouse inoculations in selecting resistant seedlings and instead, take them directly to the field. These workers believe that the discovery of the sexual stage in the field in Mexico explains the prevalence of the varied and highly specialized races in that country. Another reason that these workers prefer initial field tests is that the races occurring in nature are capable of severely blighting or killing any clone or species in the extremely favorable conditions of greenhouse inoculations. As to the advantage of field selection in Mexico, it is pointed out that blight-resistant selections made in previous years continue to show the same level of field resistance observed when the selection was first made; some of these selections have been exposed to a severe attack for 5 years. Each year these selections showed some blight particularly on the lower leaves, but still produced an acceptable crop of potatoes in Mexico.

It has been pointed out by some late blight workers that selections made in Mexico with a high degree of field resistance may not necessarily show the same degree of resistance when grown in certain potato producing areas of the United States and Canada. The different environmental conditions of these areas may influence the expression of resistance. It is known that a similar type of field resistance in tomato is altered by differences in host nutrition and environment.

Search for additional resistance.—When it became evident that clones containing the 4 known resistance genes were susceptible to race *1,2,3,4*, a search for new and different resistance genes was initiated by several workers. Since the presently recognized 4 dominant R genes were obtained from *S. demissum*, this species was reexamined for the possible presence of other R genes. Workers in Canada report the discovery of at least one new R gene in *S. demissum*. After screening a large number of accessions of this species maintained by the Interregional Potato Introduction Station and the Commonwealth Potato Collection, workers in Scotland and West

Virginia also conclude that at least one hitherto unidentified R gene is present in the homozygous condition in many of the accessions. The reactions of many of the *S. demissum* accessions suggested that various levels of field resistance also were present in the different accessions. It should be noted here that all accessions of *S. demissum* tested in the field in Mexico were attacked by late blight but showed varying levels of field resistance.

In addition to work with *S. demissum,* some attempts to evaluate the resistance in other *Solanum* species has been made. The workers in Scotland and West Virginia state that the reactions of certain progenies of *S. bulbocastanum, S. pinnatisectum, S. polyadenium* and *S. stoloniferum* suggests that these species may also possess resistance genes corresponding to the R genes in *S. demisum.* It has not been determined whether such genes in the different species are identical. Other species having accessions with resistance to race *1,2,3,4* were *S. guerreroense, S. oxycarpum, S. polytrichon, S. spectabile* and *S. verrucosum.*

Species tested in Canada showed that *S. morelliforme* and *S. clarum* possess few genes corresponding to the R genes. Work with *S. bulbocastanum* revealed resistance to race *1,2,3,4* in three of ten cellections made in Mexico. Cytological tests have revealed that the previously reported resistant *S. andigenum* plants actually are *S. demisum* hybrids and owe their resistance to this source.

In Mexico, all *Solanum* species planted in the field were found to have blight lesions. These species included *S.. bulbocastanum* previously regarded as the most resistant species in Mexico; however, these clones showed varying degrees of field resistance.

Physiologic races of P. infestans.—Physiologic specialization by the fungus continues to be studied by some workers. Race surveys are being made in some areas and tend to show that the race population is dependent upon the resistant genotypes grown. It was pointed out last year that gene R_4 was of little value in a practical program of oreeding for resistance due to the preponderance of race 4 in most areas where late blight is a problem.

As pointed out last year, Canadian workers have an isolate which attacks plants resistant to race *1,2,3,4.* They have tentatively labeled this isolate as race *1,2,3,4,5.* These workers as well as those at West Virginia have noted that one isolate of race *1,3,4* attacks clones resistant to an isolate of race *1,2,3,4* but that other clones are resistant to both isolates. This isolate might be tentatively labeled race *1,3,4,6* according to the present system of race nomenclature. This suggests the presence of a sixth R gene in *Solanum* species.

The matter of differences in aggressiveness between isolates having the same race characteristics has been of concern to some workers. It is known that the fungus is able to overcome R-gene resistance with a mechanism of developing R-gene specific races. It is postulated by some that the fungus is able to overcome polygenic field resistance through a mechanism of increasing in aggressiveness. If this is true, then it is possible that varieties with a high degree of field resistance eventually may be severely attacked by late blight. However, present evidence indicates that this does not occur or occurs very slowly. As an example, selections made and grown for 5 years in Mexico, where the sexual stage probably facili-

tates a high degree of physiologic specialization, showed the same levels of resistance in 1957 as they did in 1952.

The sexual stage of P. infestans.—Last year it was reported by workers in West Virginia and Mexico that oospores of *P. infestans* are formed in great abundance when isolates of opposite mating type are paired. It was pointed out that over 100 isolates of the fungus from the United States, Canada and Europe all acted as one and the same mating type, whereas in Mexico, both mating types were present among 95 isolates in a ratio of 1:1. It was pointed out that the oospores were functional in that they would germinate and infect potato plants. These oospores were found to occur in naturally infected plants growing in Mexico.

It was not known whether the two mating types differed in sexual morphology or in compatibility. Recent work by some of these same workers shows that isolates in both mating types are bisexual and that the original mating types actually are controlled by compatibility factors.

Some work with single oospore cultures derived from crosses of different races indicates that hybridization occurs giving rise to races different from either parent.

Other work toward control of late blight.—As in the past a great deal of other work toward control of late blight has been going on. New chemicals are being tested to determine their fungicidal value, progress in reduction of the amount of overwintering inoculum is being made in some areas, and epidemiological work is being carried out resulting in more accurately forcasting late blight and issuance of spray warnings. Progress in all of these areas go along with progress in the development of resistant varieties to give more effective control of the late blight disease.

CALL FOR PAPERS

The 42nd Annual Meeting of the Potato Association of America will be held in conjunction with the A.I.B.S. meeting at Indiana University in Bloomington, Indiana, August 24 through 28, 1958. Other societies meeting at the same time include the American Phytopathological Society, the Mycological Society of America, and the American Society for Horticultural Science.

Please send titles of papers to be presented at this annual meeting to Robert V. Akeley, Crop Research Division, Plant Industry Station, Beltsville, Maryland by April 15. Along with the title please include (a) approximate time required to present your papers, (b) if an illustrated talk, the size of the slides to be used, and (c) the names and official addresses of the authors as you wish them to appear on the program. As has been our custom, we will again distribute mimeographed abstracts of these papers to persons attending the annual meeting. Abstracts should accompany the titles of the papers and are limited to 150 words.

We would like to receive good papers concerned with problems in potato breeding, diseases, production, quality, nutrition, storage, transportation, and marketing.

Your cooperation in sending in titles and abstracts as early as possible will aid in the mimeographing of these abstracts and the prompt preparation and printing of programs. Titles received after the deadline may not be accepted. Please bring this notice to the attention of your students and colleagues.

R. V. AKELEY, *Secretary*

ABSTRACTS OF PAPERS PRESENTED AT THE FORTY-FIRST ANNUAL MEETING

ANDERSON, R. E.

SHELF LIFE OF CONSUMER-PACKAGED PRE-PEELED POTATOES STORED AT VARIOUS TEMPERATURES

The extreme perishability of pre-peeled potatoes has largely limited commercial processing to those for institutional users. Studies were conducted at Beltsville, Maryland in 1957 to determine the shelf life of pre-peeled potatoes packaged for consumers and stored at different temperatures. Lye-peeled potatoes freshly cut into french-fry strips and treated with sulfur dioxide to prevent discoloration were obtained from commercial processors and repacked in perforated or non-perforated 1-pound polyethylene bags. The average shelf life was less than 1 day at 85° F., 1 day at 70°, 2-3 days at 60°, 3-4 days at 50°, 8-12 days at 40°, and at least 14-15 days at 32°. At 40° the shelf life in the perforated bags was 12 days but in the non-perforated only 8-9 days. At other temperatures differences in keeping quality of potatoes in perforated and non-perforated bags was slight to negligible.

BENSON, A. P., AND W. J. HOOKER

RECOVERY OF VIRUS X FROM "IMMUNE" POTATO VARIETIES *(SOLANUM TUBEROSUM L.)*

Approach grafts were made to varieties of potato considered to be immune to virus X (S.41956, Saco, and Tawa). To these stocks, scions were grafted with *Datura stramonium* var *tatula L.* or with X free clones of *Solanum tuberosum L.* (Erlaine selfed), or with Irish Cobbler infected with virus X. Inoculations to virus X free scions were made with a necrotic strain of virus X (X-5) 14 days after grafting. Grafts of all plants were cut 7 days after inoculation. Thus a plant was produced with a single top (scion) carrying virus X on a resistant stock. Recovery of virus X was attempted from the following basal portions of grafted stocks: (1) the complete root system, (2) sections 4 to 6 mm. long located 1.5 to 2.5 mm. below the graft union, (3) from a stem section 4 to 6 mm. long at the soil line, (4) and from necrotic buds, if present.

Virus X was recovered from portions of grafted plants by rubbing to healthy *D. stramonium*. For each isolation, a leaf of each of 2 plants was ground in a mortar and rubbed against another plant which served as a control. The other 2 plants were inoculated with test suspensions from grafted potato. In no case was there any evidence of virus X in the control plants.

Symptom expression required from 5 to 23 days incubation. Virus X was recovered from tissue of S.41956 in 11 of the 35 plants tested in location 1, 11 of the 23 plants tested in location 2, 4 of 23 in location 3, and 1 in location 4. Of 27 Saco plants tested, virus X was recovered from tissues 5 times in location 1, 3 times in location 2, and 2 times in location 3. Virus X was recovered from tissues of 20 plants of the Tawa variety, 7 times from location 1, 4 times from location 2, and 0 times from location 3.

BIRTH, GERARD S., AND KARL H. NORRIS

A NON-DESTRUCTIVE TECHNIQUE FOR DETECTING INTERNAL DISCOLORATION IN POTATOES

A recently developed technique for measuring the spectral trasmittance characteristics of intact agricultural products has been applied to the detection of internal defects in potatoes. By this means it has been possible to show the presence of internal discolorations in potatoes which are not visible externally. This technique has been shown to be applicable to the detection of hollow heart because of the slight discoloration associated with the defect. A ratio of the transmittance of light at two wave lengths in the near infra red is used as the criterion to detect the presence of hollow heart. An instrument using narrow-band interference filters to secure the two necessary wave lengths is described for this specific application.

BONDE, REINER, ROBERT AKELEY, AND DONALD MERRIAM

PROGRESS IN THE DEVELOPMENT OF RING ROT RESISTANT POTATO VARIETIES

The control of bacterial ring rot continues to be an important problem in the potato industry. Although the losses have been greatly reduced by the use of disease-free seed stocks and the adoption of sanitary measures, it would be desirable if ring rot resistant or immune varieties can be developed that also possess desirable cultural and marketing qualities.

Seedlings have been developed by breeding methods that are more resistant to infection than the resistant varieties Saranac, Teton and Merrimack. Some have been severely inoculated with viable bacteria for 12 successive years without becoming infected in contrast with 5 to 15 per cent infection in the above-named resistant varieties and nearly 100 per cent infection in Katahdin, Cobbler, Kennebec and some other susceptible commercial varieties. Some of the ring rot resistant seedlings are also immune or highly tolerant to the late blight races O, R_1, R_2, and R_4. Progress has been made in combining ring rot resistance with resistance to common scab, leaf roll and the mosaic diseases. Studies are being conducted to obtain information about the inheritance of ring rot resistance.

CRAFT, C. C., H. W. SIEGELMAN, AND W. L. BUTLER

EFFECT OF STORAGE TEMPERATURES ON PHENOLIC CONTENT OF POTATO TUBERS

Chlorogenic and caffeic acids were identified in Russet Rural potatoes by a number of independent criteria. The phenolic content of Russet Rural and Kennebec potatoes was quantitatively estimated at monthly intervals during 5 months of storage at 55°, 40° and 32° F. Total phenolics and o-dihydroxyphenolics did not change significantly during 5 months of storage at 55° and 40° or 4 months at 32°. Both varieties stored longer than 4 months at 32° showed evidence of low-temperature injury and the o-dihydroxyphenolics had increased significantly. After-cooking darkening was not serious in the samples studied but was most evident in the Kennebec tubers stored at 55°.

DIONNE, L. A.

A SQUASH METHOD FOR POLLEN TUBES IN *SOLANUM* STYLES

A rapid and consistent method for staining pollen on stigmas, and pollen tubes in styles of *Solanum* was obtained as follows: The styles were fixed in ethyl alcohol-acetic acid 3:1 for 1 hr., and hydrolyzed at 60° C. for 5 to 60 min. in 45 per cent acetic acid. The stigma with its attached strand(s) of stigmatoid tissue was then dissected out under a stereoscopic microscope, placed in a few drops of a staining solution made by dissolving 150 mgs. of safranin O and 20 mgs. of analine blue in 25 mls. of hot 45 per cent acetic acid. After approximately 10 minutes in this stain, the tissue was placed in a fresh drop of stain on a microscope slide and gently squashed under a cover glass. Because of a gradual precipitation of the aniline blue component, the stain had to be filtered regularly before use. However, a staining solution could be kept at room temperature for several weeks.

DIONNE, L. A.

A SURVEY OF METHODS FOR OVERCOMING CROSS-INCOMPATIBILITY BETWEEN CERTAIN SERIES OF THE GENUS *SOLANUM*

Numerous methods were tried for stimulating growth of pollen tubes in incompatible crosses between series of *Solanum*. All these trials were unsuccessful including stylar grafts and hundreds of tests of the Swaminathan "artificial stigma" method. Lack of seed following interspecific crosses was found to be referable to two general causes: (1) too few ovules are reached by pollen tubes to stimulate growth of the ovary, and (2) pollen tubes never reach the placental tissues with a consequent complete lack of fertilization. Hybrid seed were readily obtained when mechanism (1)

was operating by treating the ovary with 3-6 ppm. of 2-4,D following a period of 24 to 48 hrs. after pollination. By this method seeds were obtained from many otherwise "impossible" combinations.

A genetic mechanism for overcoming the incompatibility of type (2) offers a promising method for producing hybrids when this block to fertilization is operating.

EASTON, G. D., R. H. LARSON, AND R. W. HOUGAS

IMMUNITY TO POTATO VIRUS Y

Seven tuber clones and 1 selection from true seed of *Solanum stoloniferum*, 1 tuber clone and 2 seed selections of *Solanum antipoviczii*, and 1 seed selection of *Solanum tlaxcalense* were immune to virus Y by mechanical aphid and graft inoculation. Clonal tuber lines of each of *Solanum cardiophyllu, Solanum chacoense, Solanum gibberulosum, Solanum gigantophyllu, Solanum kesselbrenneri, Solanum polyadenum, Solanum rybinii, Solanum saltense*, and 6 clonal tuber lines of *S. stoloniferum* were susceptible by mechanical inoculation.

Thirteen clonal tuber lines of *Solanum* species hybrids of 22 tested were immune to both mechanical and graft inoculation. Nineteen of the 22 lines tested contained the virus-Y-immune *S. stoloniferum* as one parent, and six of these 19 lines were susceptible on mechanical inoculation.

On inoculation by sap, aphid, or graft, three different reactions to virus Y were found: 1) systemic infection and mosaic with virus recovery, 2) hypersensitivity, variable as local lesion and/or necrotic reactions with virus recovery from only a few plants, 3) immunity with no visible reaction and no virus recovery

Passage of virus Y through the intermediate scions of virus-Y-immune *Solanum* species and species hybrids, grafted between virus-Y-susceptible tomato or tobacco top and stock tissue, always occurred downward. Upward passage of the virus occurred in only one case. Virus Y was never detected in nor recovered from intermediate immune scion tissue either by, 1) the "spot necrosis" reaction with virus X in tobacco or, 2) by a graft test using lateral bud growth as scions or, 3) by aphid transmission.

ERICKSON, H. T.

POTATO SCAB CONTROL ON ORGANIC SOILS: I. INITIAL AND RESIDUAL RESPONSE TO PCNB

On muck soils in Indiana where potato scab incidence was high 200 pounds of PCNB (pentachloronitrobenzene) was necessary for satisfactory control. Material was broadcast and disced in prior to planting. Response was essentially linear up to 200 pounds leveled off at increasing rates.

PCNB had no effect on yield, tuber size or dry matter. Rhizoctonia control was evident by the reduced incidence of black scurf in treated lots. The Katahdin variety was used.

Very little residual control appeared the year following the initial application.

GALINDO, J., AND M. E. GALLEGLY

COMPATIBILITY TYPES IN *PHYTOPHTHORA INFESTANS*

Previous work with paired cultures has revealed the presence of two mating groups in *P. infestans;* it was not known whether isolates in the two groups differed in compatibility type or in sexual morphology. Results from tracing antheridial and oogonial hyphae leading to oospore formation show that isolates in the two groups differ in compatibility type and not in sexual morphology. Each isolate, when paired with an isolate of opposite type, has the ability to form antheridia and oogonia but normally is self-sterile. Some isolates occasionally produce oospores from antheridia and oogonia of the same thallus. An isolate may act either as a male, a female, or both, depending upon the isolate with which it is paired. Thus, functional heterothallism exists in the species with each isolate being potentially homothallic. The technique used in tracing the hyphae was a modification of that used by Norasiuhan.